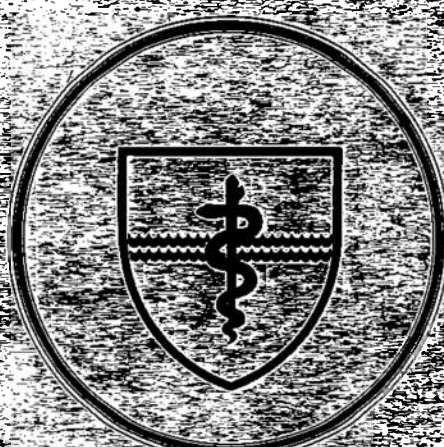


# NAVAL SUBMARINE MEDICAL RESEARCH LABORATORY SUBMARINE BASE, GROTON, CONN.



REPORT NO. 1075

## BIMODAL INFORMATION PROCESSING IN A SONAR TASK

by

David A. Kobus

and

Lawrence Lewandowski

Naval Medical Research and Development Command  
Research Work Unit M0100.001-1021

Released by:

C. A. Harvey, CAPT, MC, USN

Commanding Officer

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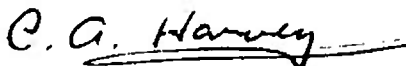
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David A. KOBUS, LT, MSC, USNR and Lawrence LEWANDOWSKI, Ph.D.

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## SUMMARY PAGE

### THE PROBLEM

To determine if choice reaction time is fastest and most accurate to targets presented to the visual, the auditory, or to both modalities.

### THE FINDINGS

Choice responses to the same targets presented in two modalities simultaneously were at least as fast and more accurate than responses to the target in either the visual or auditory modality.

### APPLICATION

The finding that an operator can choose a correct target presented in two modalities as fast and more accurately than he can to a target in one modality supports a dual-modality approach to sonar tasks.

### ADMINISTRATIVE INFORMATION

This research was conducted as part of Naval Medical Research and Development Command Work Unit M100.001-1021 Auditory Sonar. It was submitted for review and approved for publication, and designated as NSMRL Report No. 1075.

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## ABSTRACT

Target stimuli above noise backgrounds were presented to 28 men in either the visual or auditory modality, or in both at once. Subjects responded as quickly as possible whether or not a particular target was presented. Reaction times were not affected when subjects had to divide their attention between two modalities. In fact, the choice response in the dual-mode condition was as fast as the faster single modality (auditory) and more accurate than either single modality. However, when conflicting targets were presented to two modalities at once, response accuracy was lowered. The results support the findings of Lewandowski and Kobus (14) that the speed of detection and recognition of sonar-like targets is faster when the information is presented to two modalities at once and the information in each modality is functionally the same.



Under certain conditions an individual can respond to two sources of information as fast and as accurately as he can to one. This is particularly true when these sources lie within the same modality and provide redundant information (3-5). Similar findings have been reported in studies in which the two sources of information are the visual and auditory modalities. That is, redundant information presented in two modalities can improve response sensitivity or speed in comparison to one modality presented separately (1-3, 6-8). This "redundant signals" effect has been particularly evident in studies with a focus on signal detection sensitivity and/or accuracy. Some of these studies have found superior detection performance in a dual-modality presentation as compared to either single modality presentation (2,6,9-10).

Miller (3) has suggested that such findings support a "coactivation" model for explaining bimodal information processing. This model claims that activation from two sources (e.g., visual and auditory) "combine in satisfying a single criterion for response initiation" (p. 248). The result is a performance in the dual-modality condition which is better (i.e., faster or more accurate) than that of either the visual or auditory modality alone.

Studies which have compared single and dual-modality presentation conditions on sonar-like tasks have yielded mixed findings (1, 10-13), although most investigators have concluded that a combined visual and auditory approach should be retained in sonar operation. Recently, Lewandowski and Kobus (14) found that detection threshold was lowered by more than 1.2dB to both visual and auditory targets when they were presented simultaneously rather than separately. They suggested that their simulated sonar task could be used to evaluate response speed and performance accuracy under conditions of single and dual modality stimulation.

The question of response speed facilitation in bimodal stimulus conditions has been controversial. Some suggest that a response to two redundant stimuli in two modalities is faster than a response to one stimulus in either modality (coactivation) (3,8). Others have stated that reaction time (RT) to redundant bimodal stimuli is shorter than RT to the slower single stimulus, but no shorter than RT to the faster single stimulus (12,15). It appears that the RT results are confounded by the inherent differences between auditory and visual processing time. Adjusting the onsets of these two stimuli to eliminate this difference is not operationally meaningful. Instead one needs to interpret sensitivity and accuracy. In other words, if bimodal processing is at least as fast as single mode processing, yet more sensitive in detection and accurate in decision-making, then a bimodal approach to sonar operations would be supported.

In this study, the sonar-like paradigm developed by Lewandowski and Kobus (14) was employed to examine choice RT and accuracy to targets presented in one or both modalities. Comparisons were made between performance with focused and divided attention. The effect of target redundancy and non-redundancy also was examined.

## METHOD

Subjects: Twenty-eight men aged 17 to 29 years ( $M = 20.8$  years) participated. All had or were corrected to 20/20 visual acuity and displayed hearing within the normal range in routine audiometric testing.

Apparatus: Visual and auditory signals were initiated by separate Wavetek programmable synthesized function generators (Model 278) and displayed via a monochromatic visual display unit (VDU) and Koss PR04-AAA headphones. Each signal was fed through separate Hewlett-Packard 350D attenuators (at a constant setting) prior to display. The noise source consisted of pre-recorded ambient sea noise played on a Hewlett-Packard 9664A instrumentation recorder. The noise signal was split into two channels and routed through separate attenuators (at a constant setting) to the VDU and headphones.

The visual display was the AN/BQR-20A and provided signal frequency along the X-axis and time along the Y-axis. Visual noise appeared as randomly illuminated pixels varying in intensity. Amplitude of the signal and noise was represented along the Z-axis which controlled the intensity of each pixel. A horizontal line of pixels appeared at the top of the display and moved in a "waterfall" fashion down the screen (64 lines present at a time), such that each line was visible for 6.2 seconds. A visual target was presented at either 600 Hz on the left side of the display, or 1700 Hz on the right side of the display. The target appeared as an intermittent vertical arrangement of dots of greater intensity than the background noise. The amplitude of the visual noise was 60dB-re:micobar (all amplitudes were measured after attenuation). The amplitude of the visual signal was superthreshold (85dB-re:micobar).

The auditory targets were either a 600 Hz or 1700 Hz signal producing a low- or high-pitched intermittent tone. Targets were presented as tone bursts triggered at a 2 Hz rate with a 2ms pulse width. They were presented superthreshold at the same amplitude as the visual signals (85dB-re:micobar). The one-button relay switch was connected to both auditory and visual signal inputs, and to a digital time. When the button was depressed, the switch was closed and one or more signals were presented simultaneously with the initiation of the clock. When the button was released, the switch was opened and the clock and signals were stopped. Reaction time (RT) was recorded in milliseconds.

Procedure: Subjects were seated in front of the VDU at a viewing distance of 80 cm. Headphones were worn for most of the study. The experiment ran for approximately an hour including a short break after the first 60 trials.



Subjects were given a thorough description of the task, a demonstration of each stimulus condition, and 36 practice trials (6 per condition). Each subject was asked to either look at the VDU, listen over headphones, or both, and hold down a response button to initiate a trial. The subject responded to the signals by releasing his finger and saying "yes" if, for example, a high target (1700 Hz) was presented or "no" if it was not. In the second half of the experiment, subjects responded "yes" when a low target (600 Hz) was presented. All subjects were first presented with two blocks of ten single target trials in which attention was focused completely on the stimulated modality. Half of the subjects received a block of auditory trials first and half visual trials first. Next, subjects were told to divide attention between modalities and expect a target in one or both modalities. Forty trials were presented in a random order such that the following stimuli were presented on ten trials each: auditory, visual, bimodal redundant, and bimodal non-redundant. In the second half of the experiment 60 trials were presented beginning with the two blocks of focused attention trials and then forty randomized divided attention trials. Of the 120 trials, 70 were "yes" trials, in which a specified target was presented.

### RESULTS

Median RTs were computed separately for YES and NO trials within each of the six conditions (the bimodal different condition contained all YES trials). Comparisons of YES versus NO median RTs yielded no significant differences for any of the conditions; therefore, data were collapsed across YES and NO trials by computing the median of all 20 trials in each condition.

The means of the median RTs of each condition and percent accuracy scores for divided attention conditions are presented in Table 1. An analysis of variance for repeated measures on RT data revealed a significant effect of condition ( $F(5,27)=9.73$ ,  $p<.01$ ). Multiple comparisons were performed using the Tukey HSD procedure. Of the focused attention conditions, auditory RT was faster than visual RT. Among the four divided attention conditions, auditory, bimodal redundant, and bimodal non-redundant RTs were equivocal and each was significantly lower than the visual RT. Comparisons across focused and divided attention conditions indicated that RT to a visual target with attention either focused or divided was significantly longer than the latencies of all other conditions.

An analysis of variance for repeated measures was performed on the accuracy data in the four divided attention conditions. There was a significant difference in accuracy among the conditions ( $F(3,37)=24.66$ ,  $p<.01$ ). Multiple comparisons based on the Tukey HSD procedure showed that subjects made more errors when they received two conflicting targets than in any other condition. They also were more accurate when they saw a target alone, or saw and heard the same target, than if they merely heard a target.

## DISCUSSION

The present study has shown that subjects responded fastest when they heard a target, or both heard and saw the same target. However, accuracy was significantly better when the target was presented simultaneously in the visual and auditory modalities rather than only one modality. These findings are of special concern due to the recent de-emphasis of auditory sonar. The major emphasis on sonar system development has been concerned with visual displays. The sensitivity of visual displays has historically been better than that of the auditory displays, especially when tested in isolation. Yet, as stated above, when the target information was presented to both modalities simultaneously, response times were fastest and accuracy highest. These results indicate that when the sensory information from both modalities is integrated, response time decreases and accuracy increases. In conjunction with our previous findings (14), the present results further support a bimodal approach to sonar operation.

It should be pointed out that when attention was focused on a single modality, reaction time performance was best for the auditory modality. However, rather than a detection type of task, the targets in this study were presented at a suprathreshold level. Therefore, these results are as would be expected in a sensory reaction time task (auditory < visual).

It should also be stressed that sonarmen seldomly operate under a condition of directed attention. Rather, sonarmen are routinely bombarded with information presented to both modalities simultaneously. This information may or may not be redundant or even related to the task at hand. The present results demonstrate that under such conditions sonar performance could be enhanced or inhibited depending upon the stimulus characteristics. When information was redundant, reaction time and accuracy was best. When information was unrelated, reaction time was still low but accuracy was at its poorest.

These results demonstrate the negative effect that interfering stimuli have upon sonar performance. Many times sonarmen make decisions related to targets of interest while exposed to many types of competing and irrelevant stimuli. It will be a task of future research to determine which types of information are required for sonar operation and to determine if non-task specific information can be eliminated from present sonar displays.

TABLE 1

Mean Reaction Times and Percent Accuracy Scores for Focused and Divided  
Attention Conditions

CONDITION	MEAN RT(ms)	% ACCURACY
Auditory - focused	453	a
Visual - focused	532	a
Auditory - divided	478	94.5
Visual - divided	585	96.4
Bimodal - redundant	463	97.9
Bimodal - non-redundant	479	84.0

(a) Trials in these conditions were not presented randomly and subjects knew where the superthreshold target would be presented. Errors were made by only a few subjects. Therefore, the accuracy data for these conditions were not included in this analysis.

## REFERENCES

1. Nickerson, R.S. (1973). Intersensory facilitation of reaction time: Energy summation or preparation enhancement? Psychological Review, 80, 489-509.
2. Burns, D. (1970). A dual-task analysis of detection accuracy for the case of high target-distractor similarity: Further evidence for independent processing. Perception & Psychophysics, 25, 185-196.
3. Miller, J. (1982). Divided attention: Evidence for coactivation with redundant signals. Cognitive Psychology, 14, 247-279.
4. Hershenov, M. (1962). Reaction time as a measure of intersensory facilitation. Journal of Experimental Psychology, 63, 289-293.
5. Loveless, N.E., Brebner, J. & Hamilton, P. (1970). Bisensory presentation of information. Psychological Bulletin, 73, 161-199.
6. Eriksen, C.W. & Eriksen, B.A. (1979). Target redundancy in visual search: Do repetitions of the target within the display impair processing? Perception & Psychophysics, 26, 195-205.
7. Kinchla, R.A. (1974). Detecting target elements in multielement arrays: A confusability model. Perception & Psychophysics, 15, 149-158.
8. Grice, G.R., Canham, L. & Boroughs, J.M. (1984). Combination rule for redundant information in reaction time tasks with divided attention. Perception & Psychophysics, 35, 451-463.
9. Halpern, J. & Lantz, A.E. (1974). Learning to utilize information presented over two sensory channels. Perception & Psychophysics, 16, 321-328.
10. Hanson, V.L. (1981). Processing of written and spoken words: Evidence for common coding. Memory and Cognition, 9, 93-100.
11. Kobus, D.A., Russotti, J., Schlichting, C., Haskell, G., Carpenter, S. & Wojtowicz, J. (1986). Detection and recognition performance of sonar operators in a multimodal task. Human Factors, 28(1), 39-45.
12. Lewandowski, L.J., Hursh, S. & Kobus, D.A. (1985). Multimodal versus unimodal information processing of words. Naval Submarine Medical Research Lab Report No. 1056, Groton, CT.
13. Colquhoun, W.P. (1975). Evaluation of auditory, visual, and dual-mode displays for prolonged sonar monitoring in repeated sessions. Human Factors, 17, 425-437.
14. Lewandowski, L.J. & Kobus, D.A. (1985). The effects of bimodal presentation of stimuli and noise on target detection. Naval Submarine Medical Research Lab Report No. 1058, Groton, CT.
15. Mulligan, R.M. & Shaw, M.L. (1981). Attending to simple auditory and visual signals. Perception & Psychophysics, 30, 447-454.

16. Shaw, M.L. (1982). Attending to multiple sources of information: The integration of information in decision making. Cognitive Psychology, 14, 353-409.
17. Brown, A.E. & Hopkins, H.K. (1967). Interaction of the auditory and visual sensory modalities. Journal of the Acoustical Society of America, 41, 1-6.
18. Fidell, S. (1970). Sensory function in multimodal signal detection. Journal of the Acoustical Society of America, 47, 1007-1015.
19. Baker, R.A., Ware, J.R. & Sipowicz, R.R. (1962). Vigilance: A comparison in auditory, visual, and combined audio-visual tasks. Canadian Journal of Psychology, 16, 192-198.
20. Osborn, W.C., Sheldon, R.W. & Baker, R.A. (1963). Vigilance performance under conditions of redundant and nonredundant signal presentation. Journal of Applied Psychology, 47, 130-134.
21. Adams, J.A. & Chambers, R.W. (1962). Response to simultaneous stimulation of two sense modalities. Journal of Experimental Psychology, 63, 198-206.
22. Corcoran, D.W.J. & Weening, D.L. (1969). On the combination of evidence from the eye and ear. Ergonomics, 12, 383-394.
23. Duncan, J. (1980). The locus of interference in the perception of simultaneous stimuli. Psychological Review, 87, 272-300.



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